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Defrosting Characteristics of the Thermo-King One-Ton Warehouse Refrigerating Unit, Model NC51

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Defrosting Characteristics of the Thermo-King 1-Ton Warehouse Refrigerating Unit, Model MQ51, With Gasoline and Electric Drives

1. INTRODUCTION

The potential usefulness of full reverse cycle operation of the gasoline engine driven refrigerating units for heating and defrosting was investigated by Headquarters, QM, R&D, and in this connection the Heating and Air Conditioning Section was requested to make a study of the defrosting characteristics of the 1-ton unit, being manufactured by U. S. Thermo Control Company at that time, and identified as Thermo King Model MQ51. A development contract for an improved defrosting system had been awarded by Headquarters, QM, R&D and it was desired to know the details of the present system to permit an evaluation of any modification.

Accordingly, tests of the defrosting characteristics of this unit were conducted, and have been completed. Conditions studied were:

a. With automatic control of defrosting cycle.

b. With manual control of defrosting cycle.

c. At 35F refrigerator temperature.

d. At 0F refrigerator temperature.

After investigating the variables listed above with the unit refrigerating an empty 600 cubic foot warehouse, other tests were made with the warehouse loaded with "C" rations to simulate a refrigerator in service, and tests were also run of the defrosting performance of this unit with the electric motor conversion drive apparatus.

2. TEST PROCEDURE

The tests with the empty warehouse were considered as the first phase. The heat transmission factor of the demountable prefabricated warehouse was determined by operating at a constant internal temperature for several days, and using the average outdoor temperature for the period involved. This method, while not as precise as similar tests conducted in a controlled temperature room, was considered sufficiently accurate for the purposes of these tests. In order to avoid the

direct effect of solar gains on the warehouse, it was shielded with canvas mounted a foot or more about the roof.

The unit was installed in the normal panel provided at one end of the warehouse. Measurements of ambient temperature, refrigerator temperature, temperature of the stored product, and many temperatures, pressures, etc., pertaining to the operation of the refrigerating unit itself were observed during the tests. Not all of the data recorded in these tests are reported here but if additional information is desired it can be summarized on request.

The Model MQ51 Thermo-King unit was provided with a timing device, operated from the engine crankshaft, which at constant speed of 2400 rpm provided an automatic defrosting approximately every 4-1/2 hours. The length of the defrost cycle was controlled by a limit thermostat which restored the unit to refrigerating service. It should be noted that the Model MQ51 was not a reverse cycle unit in that it did not refrigerate the condenser during the heating operation. The hot discharge gas was introduced into the evaporator and the heating was limited to the work performed on the gas by the compressor, with the refrigerant condensing in the evaporator. All tests were made with the refrigerator temperature at approximately 0°F and a relative humidity of 60%. During extended operation at 0F, some difficulty was experienced with the humidifier freezing up, but this did not occur so frequently as to distrub the results significantly. During the tests that were terminated when a temperature of 0F could no longer be maintained because of the frost accumulated on the evaporator coil, the refrigerator temperature would sometimes rise above 0F before the defrost operations were begun.

During the tests with the refrigerator loaded, the compressor (Thermo-King Model 4-R) failed and was replaced with another of the same model borrowed from another MQ51 unit on hand. Tests of the unit with the electric conversion drive apparatus were made with this second compressor and no comparison tests were made to determine the relative capacity of the two compressors.

3. TEST RESULTS

At 35F refrigerator temperature, in the first phase of the tests, i.e., with the empty warehouse, the defrost cycles occurred at intervals of approximately 4-1/2 hours, under automatic control, lasted from 14 to 16 minutes and the amount

of water obtained from each defrost was between 18 and 36 pounds.

The refrigerator temperature rose on the average from 35°F to 59°F during the defrost period. The rise in refrigerator temperature should be considered in the light of the manner of testing. To load the refrigerating unit to full capacity, internal heat was applied electrically with the largest amountsupplied in the case of the tests under automatic control of defrosting. When the refrigerator temperature rose above the control point, in this case 35F, the controller turned off theprincipal internal heater. The rise in refrigerator temperature was then caused by other internal heaters (fans, humidifier, etc.), heat gain through the walls, and heat given off by the evaporator unit. In the case of the tests when the defrosting was under manual control, all of the internal heat was off during the defrost, and the rise in refrigerator temperature was due to heat gain through the walls and heat given off by the evaporator unit only. In both cases defrost tests were conducted at different ambient temperatures and this, of course, affected the amount of heat entering through the warehouse walls during the various defrost tests. The warehouse used for these tests had a heat transmission factor of approximately 56 Btu/hr/°F, so that in varying ambient temperatures, the heat gain through the walls might range from 2240 Btu/hr at a 40 degree F difference to 5040 Btu/hr at a 90 degree F difference. Since similar conditions would occur in service it was not thought that these variations reduced the value of the test observations but must be considered in evaluating the results.

Under manual control at 35F refrigerator temperature the time required for the coil to accumulate sufficient frost or ice to reduce the refrigerating capacity to approximately 6650 Btu/hr was 36 hours, and the amount of water obtained from this defrost was nearly 49 pounds for the same refrigerator temperature. Fifty minutes were required to defrost and the warehouse temperature rose to 40 F during defrost.

At 0F refrigerator temperature, the frequency of defrost cycles under automatic control was once every 4-1/2 hours, the defrost period varied from 14 to 17 minutes, and the water obtained from the defrost ranged from 2 to 3-3/4 pounds. The refrigerator air temperature rose from 0°F to 30°F during defrosting. Under manual control at the same refrigerator temperature, the time required to accumulate enough ice to reduce the capacity to approximately 7200 Btu/hr was in excess of 85 hours, and the amount of water obtained during defrost was 23-3/4 pounds. The refrigerator temperature rose to 50F during

the defrost period, which lasted about 23 minutes. Under manual control, the refrigeration cycle was started after defrost by the same temperature-limit thermostat on the evaporator coil as used under automatic control.

Under the second phase, with the warehouse loaded, tests were made with the unit operated both with the gasoline engine drive and with the electric motor conversion drive. To simulate a product load the warehouse was loaded with 154 cartons of Army "C" Rations, the cases being 1.1 cubic feet in volume and weighing 39 pounds. These cases were arranged in four columns two cases wide, two cases deep and stacked approximately 9 cases high, with ventilating aisles or spaces between columns. Thermocouples were placed at numerous points in and on these columns; on the exterior carton surfaces facing the corners of the refrigerator, between two cartons and about 3" in from the outside of the column (referred to as "inside surface") and in the center of the mating surfaces between two cartons, (referred to as "center"). The temperature observations of the carton surfaces reported were all made from thermocouples mounted approximately midway from floor to ceiling.

The primary purpose of repeating these defrosting tests with the loaded warehouse was to determine the effect on general storage temperature when there was produce in the warehouse that would absorb heat as compared with our previous tests with the empty warehouse. Tests were made only at 0F refrigerator temperature.

The test with the gasoline engine drive was terminated sooner than desired because of failure of the compressor. This failure did not prevent the compressor from handling refrigerant, but it would not retain sufficient oil for adequate lubrication. Frost was accumulated for five days, at refrigerator conditions of approximately 0F and 60% r.h., with varying ambient temperatures from 46 to 92F. The defrost required 50 minutes, the amount of water obtained was 37-1/2 pounds, and the average refrigerator air temperature rose from approximately 6F to 20F. The temperatures of the cases of rations rose as follows: outside surfaces, 16 degrees (from 6 to 22F); inside surfaces, 4 degrees (from 4 to 8F); and center, none (stayed at 4F).

the defrost period, which lasted about 12 minutes. Under manual control, the refrigerating cycle was started after defrost by the same [illegible] thermostat as it operated as well as used under automatic control.

Tests [illegible], with the warehouse loaded, tests were made with the unit operating both with the gasoline engine drive and with the electric motor [illegible] drive. In simulating a product load the warehouse was loaded with 144 cartons of [illegible] cartons, the cases being 1.1 cubic feet in volume and weighing 38 pounds. These cases were arranged in four columns [illegible] and stacked approximately [illegible] high, with [illegible] between columns. Thermocouples were placed at [illegible] points in [illegible] on the [illegible] surface [illegible] the [illegible] of the refrigerator, [illegible] 1" in from the [illegible] (referred to as "inside surface") and in the center of the [illegible] between the [illegible] (referred to as "center"). The temperature [illegible] of the [illegible] reported were [illegible] from thermocouples located approximately [illegible] from floor to ceiling.

The primary purpose of operating these refrigerating tests with the loaded warehouse was to determine the effect, on [illegible] temperatures, [illegible] in the warehouse than would [illegible] as compared with [illegible] tests with the empty warehouse. Tests were made only at 10° [illegible] temperature.

The test with the gasoline engine drive was terminated earlier than desired because of failure of the generator. This failure did not prevent the compressor from [illegible], but it would not permit [illegible] for adequate [illegible]. Fresh [illegible] for five days, at [illegible] of approximately [illegible] and [illegible] r.p.m., with varying ambient temperatures from [illegible] to [illegible]. The defrost required 30 minutes, the amount of water [illegible] was [illegible] pounds, and the average [illegible] air temperature rise [illegible] approximately [illegible]. The temperatures of the [illegible] were as follows: [illegible], 10 degrees (from [illegible] to [illegible]); [illegible] (from 4 to [illegible]); and center, [illegible].

Following this test the compressor was removed and another installed. The replacement compressor was borrowed from another F 51 on hand, and had been operated during tests of that unit. It retained its oil charge and trapped out the additional oil which had been added to keep the defective compressor operating. The unit was then placed in the test calorimeter in the controlled-temperature test room and comparative capacity tests were made with the gasoline engine drive versus the electric motor conversion drive. These tests were made with a refrigerator temperature of 0F and in an ambient temperature of 110F. Under these conditions the net refrigerating capacity with the gasoline drive was approximately 9780 Btu/hr and with the electric motor drive was approximately 5970 Btu/hr. The results of these comparison tests will be covered in more detail in another report, but are significant in connection with the defrosting tests in that one such test was made with the electric motor drive. It should be noted that the operating speed of the compressor was different for the two methods of drive, 2400 rpm with the gasoline engine and 1750 rpm with the electric motor. The fans, both evaporator and condenser, were operated at the same speed for the two cases, however, by means of suitable pulley sizes.

After placing the unit back in the loaded warehouse, a defrosting test was made with the electric motor drive. Frost was accumulated for about 35 days, when the unit was unable to hold the refrigerator temperature below 12F in an ambient temperature of 75F, corresponding to a refrigerating capacity of approximately 3900 Btu/hr. The defrost required 1 hour 50 minutes and the water obtained was 69 pounds. The refrigerator air temperature rose from 12F to 32F, and the stored produce rose in temperature as follows: outside surfaces, 18 degrees (from 12 to 30F); inside surfaces, 7 degrees (from 10 to 17F); and the center, none (stayed at 10F). The temperature rise of the individual packages of "C" rations was undoubtedly less than that of the exterior surfaces of the cartons because of the insulating value of the cardborad carton.

No tests were made in the loaded refrigerator with the automatic defrosting control since it was clear that the internal temperature rise with the loaded refrigerator was materially less than with the empty warehouse, and suitable comparison data had already been obtained with the empty warehouse under manual control.

Following this test the compressor was removed and another installed. The replacement compressor was borrowed from cabinet K-11 on hand, and had been operated during tests of that unit. It retained its oil charge and because of the additional oil which had been added to keep the defective compressor operating. The unit was then placed in the test calorimeter in the controlled-temperature test room and comparative capacity tests were made with the gasoline engine drive versus the electric motor motor-generator drive. These tests were made with a cold container temperature of 0F and in an ambient temperature of 110F. Under these conditions the net refrigerating capacity with the gasoline drive was approximately 9300 Btu/hr and with the electric motor drive was approximately 8270 Btu/hr. The results of these comparison tests will be reported in more detail in another report, but are significant in connection with the laboratory tests in that the test was made with the electric motor drive. It should be noted that the operating speed of the compressor was different for the two methods of drive, 2160 rpm with the gasoline engine and 1750 rpm with the electric motor. The fans, both evaporator and condenser, were operated at the same speed for the two modes, however, by means of suitable pulley sizes.

After placing the unit back in the loaded warehouse, a defrosting test was made with the electric motor drive. Frost had accumulated for about 15 days, when the unit was unable to hold the refrigerated warehouse below 10F in an ambient temperature of 75F, corresponding to a refrigerating capacity of approximately 1600 Btu/hr. The defrost required 1 hour 50 minutes and the water drained was 60 pounds. The refrigerated air temperature rose from 10F to 32F, and the stored produce rose in temperature as follows: outside surfaces, 18 degrees (from 2F to 20F); inside surfaces, 7 degrees (from 10 to 17F); and the center, none (stayed at 10F). The temperature rise of the individual packages of the surface was considerably less than that of the exterior surfaces of the cartons because of the insulating value of the corrugated cartons.

No tests were made in the loaded refrigerator with the automatic defrosting control since it was clear that the internal temperature rise with the loaded refrigerator was materially less than with the empty warehouse, and [illegible], as data had already been obtained with the empty warehouse under manual control.

The rise in internal refrigerator temperature shows that additional work can profitably be done in regard to improving the defrost rate and at the same time contain the defrosting heat within the unit. Separate investigations of the full reverse cycle operation of the MQ51 unit are currently being made and will be reported separately. These developments can well be expected to improve defrosting operation of portable refrigerating equipment of this general type.

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